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(71) Applicant:
Electric Boat Corporation
Groton, CT 06340-4989 (US)

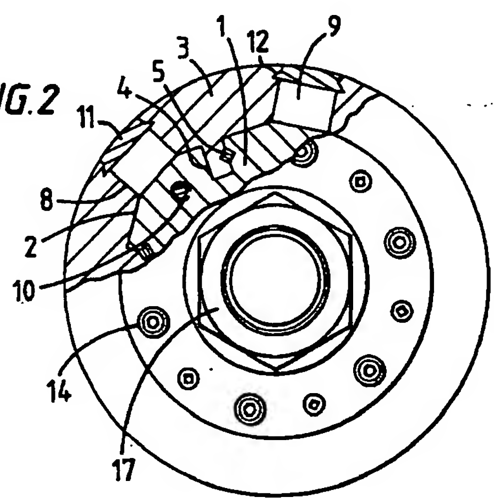
(72) Inventor: Lubas, Michael J.
Basking Ridge, New Jersey 079220 (US)

(74) Representative:
Lucas, Brian Ronald
Lucas & Co.
135 Westhall Road
Warlingham Surrey CR6 9HJ (GB)

(54) A rotor for a motor or generator

(57) A rotor for a motor or generator, said rotor comprising a rotor hub (1), a plurality of angularly distributed pole pieces (3) thereabout, and a plurality of permanent magnets (9) disposed between said pole pieces (3) characterised in that said rotor hub (1) and said pole pieces (3) have interengaging means (2, 4) which serve to position said pole pieces (3) radially and angularly with respect to said rotor hub (1).

FIG.2



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Description

This invention relates to a rotor for a motor or generator, said rotor comprising a rotor hub, a plurality of angularly distributed pole pieces thereabout, and a plurality of permanent magnets disposed between said pole pieces.

Conventionally the most commonly used integral horsepower motor rotors have a squirrel cage construction and are used in alternating current (AC) induction motors. AC and direct current (DC) generators typically include wound rotors. DC motors usually include a commutator and rotor windings. Each of these motors or generators have rotors which differ significantly from a rotor including permanent magnets. In addition, each of these rotors develop a rotor magnetic field by electrical current flowing through the rotor. As a result, all these rotors are excessively large, less efficient, more difficult to cool and of complex construction.

Heretofore, rotors including permanent magnets utilized curved magnets which were fixed with adhesive to the periphery of the rotor. Other permanent motor rotors, typically much smaller in size, utilized magnets embedded in the steel rotor core. In that case, stacks of rotor laminations which form pole pieces are generally secured to the rotor using threaded fasteners or dovetails. Use of the dovetails or fasteners typically increases rotor coat and adds excessive parts to the rotor assembly.

Unfortunately, precise location of rotor pole pieces in permanent magnet motor and generator rotors is difficult to achieve and as a result such rotors are usually noisy. Such precision is necessary when using the rotor for applications where torque fluctuations and cyclical radial loads must be kept to a minimum. Moreover, the inability to provide precise radial position and angular orientation of rotor parts can degrade overall rotor or generator performance, cause unacceptable vibration levels and reduce efficiency.

In addition, loosening of the rotor assembly can occur during operation due to normal motor or generator vibration. Loosening of parts can degrade performance or even cause mechanical damage to motor or generator parts. Vibration may also loosen or cause failure of adhesive bond lines which can result in release of the permanent magnets installed on the motor rotor. Degraded performance or mechanical damage may result from magnets which are loosened and separate from the rotor.

The use of adhesives or threaded fasteners to retain magnets on the rotor core makes the magnets susceptible to separation from excessive centrifugal or high impact shock loads imposed on the motor rotor. Moreover, motor or generator heating and environmental conditions degrade the integrity of the adhesive used to secure the magnets to the rotor, potentially leading to eventual magnet separation and rotor failure.

To help retain surface or adhesive mounted permanent magnets, a thin retaining cylinder usually of metallic or wound fibrous construction is employed. The use of such a thin retaining cylinder or can has detrimental effects on machine performance and efficiency. In addition the required cylinder thickness for a large or high speed motor or generator makes the use of such a can for these applications impractical.

Permanent magnets installed in conventional rotors, whether embedded therein or affixed with adhesive, are susceptible to damage and/or demagnetization from over-heating. Unfortunately, the magnets are directly exposed to heat effects associated with air gap surface losses, eddy current heating and heat associated with mechanical vibrations induced from air gap harmonics. Heating these magnets near their Curie temperature can cause demagnetization and result in performance loss. Moreover, shorts in simple turn-to-turn or phase-to-phase stator windings may produce dramatic heating of magnets installed in conventional rotors and thus lead to demagnetization.

Further, conventional permanent magnet rotors offer little or no protection from magnet damage or demagnetization under severe operating conditions or common motor and generator casualties. The magnets are susceptible to physical damage because they are usually located on, or have at least one side totally exposed to the rotor air gap surface. Accordingly, imposed shock loads, high vibration levels or mechanical failure of some other closely aligned motor or generator part can result in physical impact to the magnets thereby damaging the magnets.

Typically, permanent magnet rotors which utilize embedded magnets allow the pole pieces to bear directly onto the magnets. Since the magnet material is brittle, this precludes the use of these magnets as reliable stress bearing structural members in many applications, particularly where large rotors are required. Moreover, permanent magnet rotors generally use only single magnets to establish rotor poles. As the size of a permanent magnet rotor increases, single magnet configurations are more susceptible to physical damage from bending, torsional and shear stresses because, as previously discussed, these magnets are very brittle and do not contain the physical strength associated with other metallic rotor components.

In addition, the single magnets used to create poles in conventional permanent magnet rotors may become difficult and hazardous to handle as the rotor size increases. Typically, permanent magnet rotors utilize powerful rare earth magnets that have strong magnetic fields. Handling of such physically large magnets, each with a large magnet field requires development of special tooling and procedure to handle the magnets. Working with large magnets in the vicinity of surrounding ferromagnetic material may also pose safety hazards to personnel.

Further, the difficulties in manufacturing and magnetization of large size single magnets limits the size

and ratings attainable in conventional pulse modulated motor and generator designs.

Accordingly, there is provided a rotor for a motor or generator, said rotor comprising a rotor hub, a plurality of angularly distributed pole pieces thereabout, and a plurality of permanent magnets disposed between said pole pieces characterised in that said rotor hub and said pole pieces have interengaging means which serve to position said pole pieces radially and angularly with respect to said rotor hub.

Further features of the invention are set out in Claims 2-9.

There is also provided a method of constructing a rotor in accordance with the present invention, which method comprises the step of locating said pole pieces on said rotor hub by interengaging said interengaging means.

For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings, in which:

Fig. 1 is a longitudinal sectional view of a shaft provided with a rotor in accordance with the invention;
Fig. 2 is an end view, partly in section, of the embodiment of Fig. 1;
Fig. 3 is an illustration of a pole piece positioned in the rotor hub of Fig. 1;
Fig. 4 is an illustration of an alternative pole piece positioned in an alternative rotor hub in which the angular orientation surface of the rotor is located at a lesser radial distance from the centerline of the rotor than the surfaces which control the radial position of the pole piece;
Fig. 5 is an illustration of another alternative arrangement for positioning a pole piece in another alternative rotor hub;
Fig. 6(a) and 6(b) are side and end views, respectively, showing a representative tapered key for locking a pole piece into a rotor hub; and
Figs. 7(a) and 7(b) are side and end views, respectively, along a representative slot wedge for retaining a pole piece in the rotor hub.

As shown in the representative embodiment, a rotor hub 1 supports an angularly distributed array of pole pieces 3 and includes two sets or accurate positioning surfaces 2 and 4 for positioning the pole pieces 3. The rotor hub 1 is preferably composed of a metallic material, for example aluminium, or a non-metallic material, for example ceramic, plastic or a reinforced composite material. The rotor hub 1 is constructed with a hollow center although it may be constructed as a solid piece. The pole pieces 3 comprises a stack of laminated segments or may consist of a solid block of ferromagnetic material.

One set of rotor hub positioning surfaces 2 controls the radial position of the pole pieces 3 with respect to the rotor axis. Preferably, the radial positioning surfaces 2 are a series of flat surfaces with faces tangential to an inscribed circle concentric with the rotor axis. In an alternate embodiment the radial positioning surfaces may be in the form of a series of curved surfaces which together form parts of a cylinder concentric with the rotor axis.

A second set of positioning surfaces 4 controls the angular orientation of the pole pieces 3. The positioning surfaces 4 are flat plane surfaces extending parallel to a radial plane which passes both through the centerline of the rotor and through the centerline of the pole pieces 3 which are oriented by the positioning surface 4.

As shown in Figs. 4 and 5, the positioning surfaces 4 controlling the angular orientation of the pole pieces 3 need not be located at a greater radial distance from the centerline of the rotor than the radial positioning surfaces 2. As illustrated in Fig. 5 the angular orientation surfaces 4 may be formed by projections 4a of rotor core material which engage corresponding slots in the pole pieces 3 and are secured therein by keys 5. The projections 4a may be manufactured as an integral part of the core rotor hub 1 or as an assembly of independent segments that are secured to the core rotor hub 1 as well as to the pole pieces by keys 5.

The pole pieces 3 are installed in the rotor hub 1 by inserting them radially onto the rotor hub 1. The pole pieces 3 are then locked into position on the rotor hub 1 by inserting two overlapping multiple part tapered keys 5 of the type shown in Figs. 6(a) and 6(b) axially from one or both ends of the rotor assembly. When driven into place, the keys 5 produce a wedging action which ensures the correct orientation of pole pieces 3 in relation to the positioning surfaces 2 and 4.

A single magnet or a plurality or smaller magnets 9 may be inserted axially from one or both ends of the rotor hub 1 between the pole pieces 3 after the pole pieces 3 are in place on the rotor hub 1. Temporary guide rails (not shown) guide the appropriately sized magnets into the rotor core. Threaded axial holes 10 in the face of the rotor hub 1 may be used to attach the temporary guide rails.

Generally, the magnets 9 have a rectangular shape with flat sides. In an alternate embodiment, the magnets 9 may have a concave surface which contacts a cylindrical rotor hub surface. The relative size of the magnets 9 in relation to the size of the pole pieces 3 may be decreased or increased as necessary to provide desired magnetic field strength when using different magnetic materials. The magnets 9 are sized for a close clearance fit with the adjacent pole piece faces 8 which are parallel plane surfaces. Thus the magnets 9 are held captive in the rotor assembly without being subject to any bearing loads.

The magnets 9 are restrained from moving radially outwardly due to centrifugal loading by inserting slot wedges 11, shown in Figs. 7(a) and 7(b) which are made of magnetically inert material, into slots 12 formed in the rotor pole pieces on the opposite sides of the

magnets 9. The slot wedges 11 are held captive by mechanically engaging the slots 12 in the rotor pole pieces 3. Alternatively, the rotor pole pieces 3 may be formed with suitable projections to be received in and thereby retain the slot wedges 11. In a further embodiment, the slot wedges 11 may be restrained by end plates 13, shown in Fig. 1, rather than by the slots 12 or by projections in pole pieces. The slot wedges provide physical protection for the magnets 9 during installation of the rotor assembly 1 into the stator assembly and shield the magnets from the air gap surfaces in the assembled motor or generator, thereby reducing the susceptibility of the magnets to demagnetization.

The rotor pole pieces 3 and the magnets 9 are restrained axially by magnetically inert end plates 13 which are attached to the rotor hub 1 with fasteners such as screws 14 at both ends of the rotor shaft 15. The rotor core assembly 6 is secured on a rotor shaft 15 by tapered metal portions 16 and a shaft mounting locknut 17.

Various modifications are envisaged to the above described embodiments of the invention. In particular, the rotor core assembly 6 may be secured to the shaft by shrink fitting it on thereto rather than by using tapered wedge rings 16. A key 18 extending through the rotor shaft 15 and rotor hub 1 precludes relative rotation therebetween. In an alternate embodiment, the rotor hub 1 and the rotor shaft 15 may be fabricated as a single integral unit.

In an alternate embodiment, the outer surfaces of the pole pieces 3 may include circumferential grooves to reduce eddy current losses. In another embodiment the outer surfaces of the pole pieces do not necessarily represent portions of a continuous cylindrical surface. The outer pole piece surfaces may be shaped to control the magnetic flux distribution across the air gap to the motor or generator stator. In a further embodiment, the pole pieces may be positioned so as to be skewed at an angle from a plane which coincides with the shaft centerline. This serves to smooth torque ripple. Another technique for smoothing torque ripple is to skew the stator core rather than the rotor core.

The rotors of the present invention are especially suitable for use in motors having a power output of from 2 to 70,000 shaft horsepower (1496 to 5.1×10^7KW).

Claims

1. A rotor for a motor or generator, said rotor comprising a rotor hub (1), a plurality of angularly distributed pole pieces (3) thereabout, and a plurality of permanent magnets (9) disposed between said pole pieces (3) characterised in that said rotor hub (1) and said pole pieces (3) have interengaging means (2, 4) which serve to position said pole pieces (3) radially and angularly with respect to said rotor hub (1).

2. A rotor as claimed in Claim 1, wherein said rotor hub (1) has at least two surfaces (2, 4) which engage with said pole pieces (3) positioning said pole pieces (3) both radially and angularly.

3. A rotor as claimed in Claim 2, wherein at least one of said surfaces (2) is tangential to an inscribed circle concentric with the axis of the rotor hub (1).

4. A rotor as claimed in Claim 2, wherein at least one of said surfaces (2) forms a cylinder concentric with the axis of the rotor hub (1).

5. A rotor as claimed in Claim 2 or 3, wherein at least one of said surfaces (4) is parallel to a radial plane which passes both through the axis of the rotor and through the centre line of a pole piece.

6. A rotor as claimed in any preceding claim, further comprising a key means (5) for securing said pole pieces (3) to said rotor hub (1).

7. A rotor as claimed in any preceding claim, further comprising a retainer (11) disposed between adjacent pole pieces (3) to retain the permanent magnets (9).

8. A rotor according to Claim 7, wherein said retainer (11) engages slots (12) in the pole pieces (3).

9. A rotor as claimed in any preceding claim wherein at least one of said pole pieces (3) and said rotor hub (1) comprises a projection which is disposed in a corresponding recess in the other of said rotor hub (1) and said pole pieces (3).

10. A method of constructing a rotor as claimed in any of Claims 1 to 9, which method comprises the step of locating said pole pieces (3) on said rotor hub (1) by interengaging said interengaging means (2, 4).

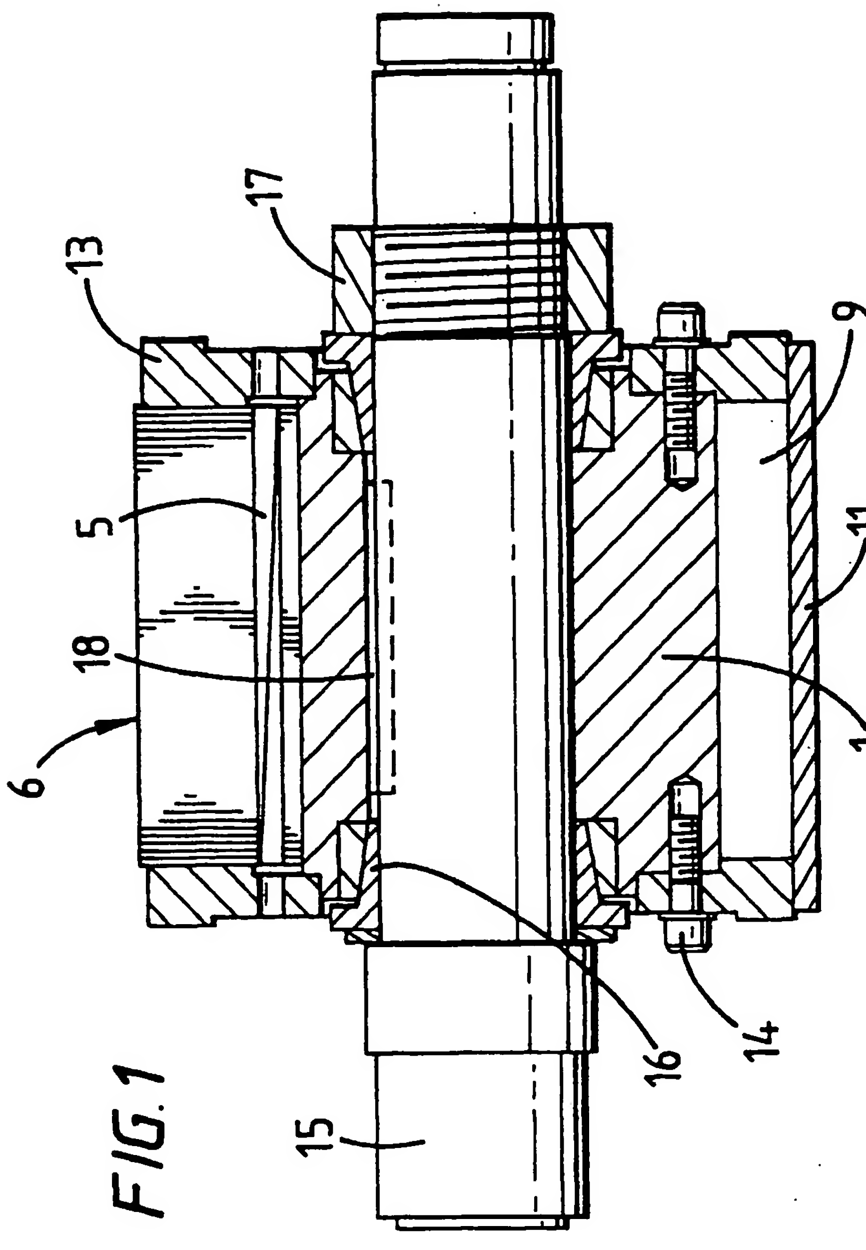

FIG.1

FIG.2

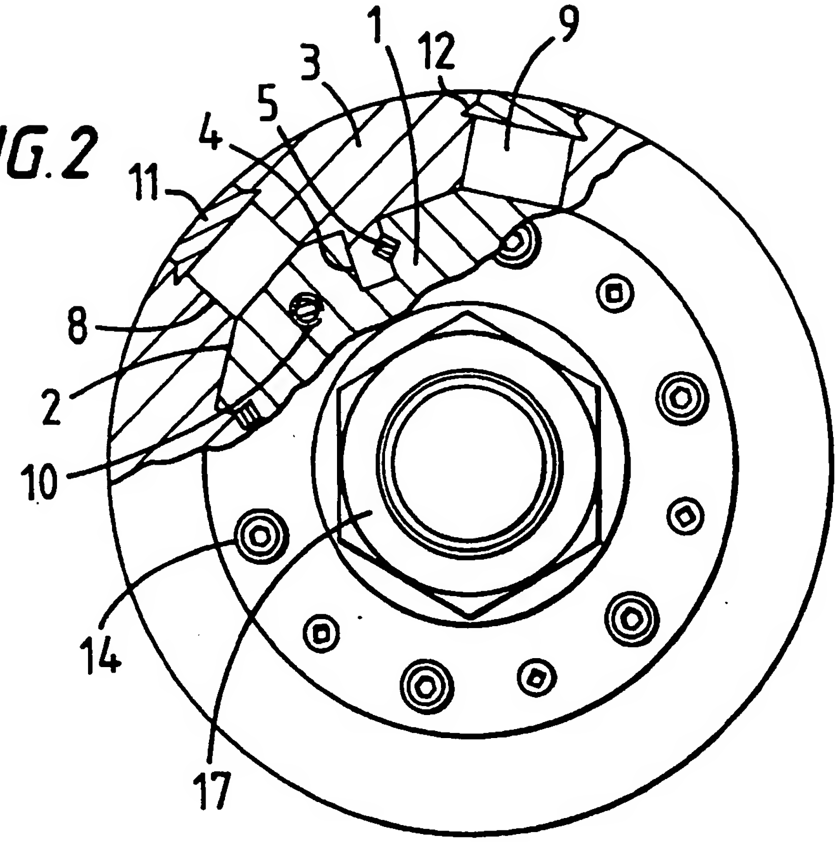

FIG.3

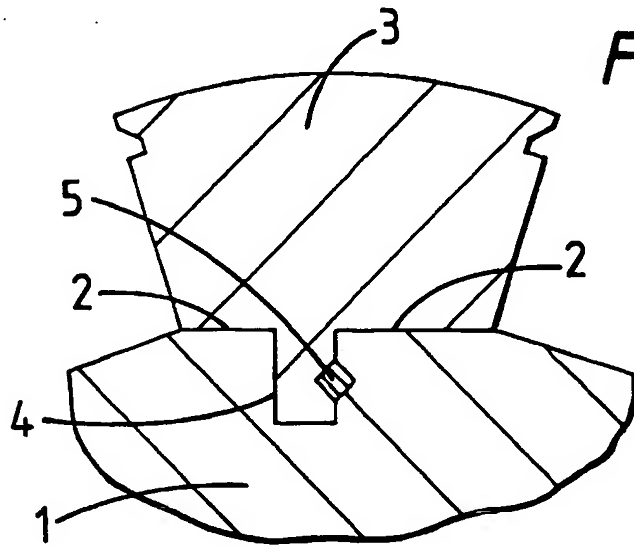

FIG.4

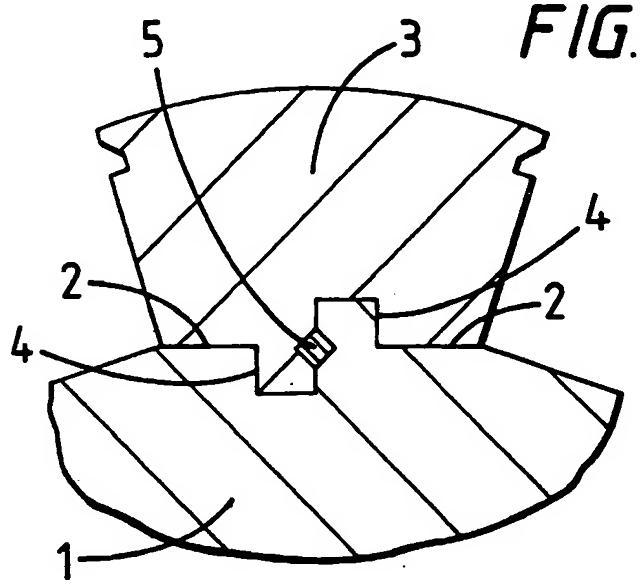

FIG.5

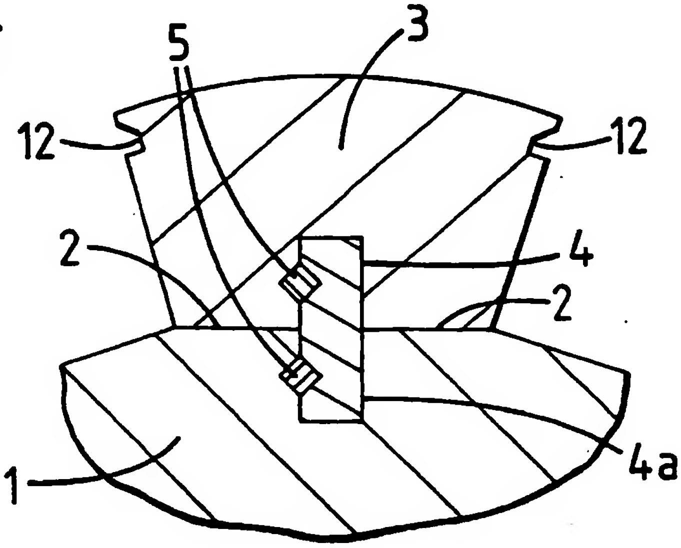

FIG. 6(a)

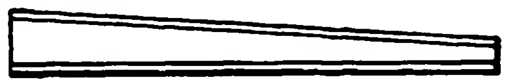

FIG. 6(b)

FIG. 7(a)

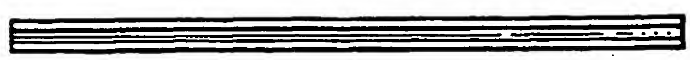

FIG. 7(b)